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1 Introduction

1.1 History

The proposed Reno Railroad Corridor is the culmination of many years of extensive analysis. For over 60 years, the City of Reno, in cooperation with various state and federal agencies, has investigated alternatives to reduce the adverse effects of railroad traffic in the downtown City of Reno area. This process included a proposal in 1936 by the United States Bureau of Public Roads to elevate the railroad. In response, the City of Reno City Engineer suggested instead that the railroad remain in its current location and that it be lowered below street level. This depressed railroad concept was intended to be less disruptive to the character of the downtown area than an elevated structure, which would create a barrier through the City of Reno. In a 1942 report, The City of Reno Chamber of Commerce subsequently endorsed the depressed trainway project, at cost estimate of $1.4 million. Updated reports endorsing a depressed railroad corridor were prepared in 1944, 1968, 1972, 1976, and 1980. Notwithstanding these endorsements, a combination of engineering infeasibility, prohibitive costs and a negative political climate continued to preclude construction of a depressed trainway through the City of Reno.

More recently, in 1996, approval of the Union Pacific/Southern Pacific Railroad merger precipitated renewed discussion of the railroad corridor through the central portion of the City of Reno. The Final Mitigation Plan (U.S Surface Transportation Board 1998) for the merger estimated that the railroad traffic through the corridor would grow substantially over current levels. A depressed trainway was then proposed by the City of Reno as a means to address the adverse effects of existing and anticipated railroad traffic.

A Memorandum of Understanding (MOU) between the Union Pacific Railroad and the City of Reno was executed in December 1998. The MOU specified UPRR's funding contribution and involvement in the project. In addition, the MOU stipulated the planning, construction, and operating relationship between the City of Reno and the UPRR. In addition, the parties agreed that the City of Reno would withdraw its appeal pending before the United States D.C. Circuit Court of Appeals in the City of Reno's litigation against the Surface Transportation Board and the Union Pacific Railroad. The outcome of these negotiations defined a City of Reno project that became known as the Reno Transportation Rail Access Corridor (ReTRAC) Project.

In June 1999, a federally sponsored process (called the Reno Railroad Corridor to distinguish it from the City of Reno's ReTRAC project) to develop preliminary engineering and environmental documentation for the project was initiated. The Federal Highway Administration (FHWA) is the federal lead agency for purposes of the National Environmental Policy Act (NEPA). The Nevada Department of Transportation (NDOT) is the contracting authority for the process. Cooperating parties include the City of Reno, Washoe County, the Federal Railroad Administration (FRA), and Union Pacific Railroad (UPRR). It is the intention of all parties concerned that modern, cost-effective engineering techniques may finally enable the depressed trainway project to be built.

The Reno Railroad Corridor would be partially funded through the Federal Highway Administration (FHWA) and would be subject to other regulatory requirements.

1.2 Overall Site Conditions

The Union Pacific Railroad tracks extend through the heart of downtown Reno in an east-west direction, in close proximity to local businesses, which include light industrial warehousing, densely populated apartments, hotels, and casinos. The construction of 11 overheads (a local road crossing over a railroad) presents engineering and project coordination challenges in the areas of utility relocation, rail alignment, property acquisition, and traffic control.

Figure 1 Project Location

It is desired to minimize overall project costs. One of the main factors in determining overall project costs is the depth of the trench. It is desired to keep the trench as shallow as possible while still allowing the 11 overheads to cross over the trench. The most economical way to accomplish a shallow trench is to use a minimal depth of overhead structure while maintaining safety and economics of the overhead. Analysis of these criteria, combined with structure costs, resulted in final overhead type selection recommendations.

The Reno Railroad Corridor involves complex geological, environmental, structural, and commercial issues. This report analyzes how effective engineering practice can be used to resolve these issues.

1.2.1 Project Structures

There are eleven (Keystone, Vine, Washington, Ralston, N. Arlington, West, Sierra, N. Virginia, Center, Lake and Evans) overheads required as part of the Reno Railroad Corridor project. All of the structures will have a length of approximately 59 feet (measured from beginning to end of the structures) in order to span the 54-foot clear width of the trench.

Based on typical sections anticipated for the crossings, the following table provides total structure width anticipated, combined with the number of design traffic lanes.

Location	Design Traffic Lanes	Anticipated Widths*
Keystone Ave.	6	88 ft → 100.5 ft
Vine St.	3	80 ft → 85.3 ft
Washington St.	2	61 ft → 66.3 ft
Ralston St.	2	68.7 ft → 74 ft
Arlington Ave.	4	80 ft → 85.3 ft
West St.	3	80 ft → 81 ft
N. Sierra St.	3	80 ft → 81 ft
N. Virginia St.	4	67 ft → 72.3 ft
N. Center St.	3	80 ft → 81 ft
Lake St.	4	80 ft → 81 ft
Evans Ave.	2	42 ft → 47.3 ft

*The width of each crossing will vary depending on the structure type selected.

Table 1 Design Lanes and Anticipated Widths

1.3. Downtown Atmosphere

The downtown hotel/casino area (Figure 2 Downtown Atmosphere) is a major source of revenue for the City of Reno. Noise, traffic disruption, business access disruption, and duration of construction would reduce the attractiveness of the area to customers and may have a major fiscal impact on businesses in the downtown area. With this in mind, it is desirable to select a overhead type that can be constructed quickly and minimize traffic disruptions in the downtown area.

Figure 2 Downtown Atmosphere

2 General Concepts

Project success is defined by an economic structure type that minimizes the impact to the remainder of the project and the surrounding area, provides adequate clearance to the underlying rail, has the capacity to carry the required utilities, and can be constructed within an acceptable timeframe.

2.1 Analysis Subjects

The Bridge Analysis Report examines multiple overhead structure types to determine the most feasible design for the Reno Railroad Corridor Project. To this end, criteria to assess the advantages and disadvantages of each proposed structure type were identified as follows:

- Construction Duration/Sequence
- Overhead Construction Costs
- Utility Considerations
- Overall Construction Impacts/Bridge Width
- Superstructure Depth
- Application
- Conclusion

In addition, conceptual calculations were completed for each of the overhead types to assess their feasibility. The following is a list, in order of appearance in the report, of all overhead types that are discussed:

- Through Girder
- PC/PS I-Girder
- CIP Box Girder
- Steel I-Girder
- Slab Post-Tensioned Slab
- Bulb Tee*
- Box Beam

*The bulb tee section replaces the double tee section that was initially considered. The double tee is typically used for spans from 30- to 60- feet. However, the large added dead loads preclude the applicability of the 54-foot clear span.

2.1.1 Construction Duration/Sequence

The construction sequence for each alternate structure type is described in this report. The sequence includes work required to construct the superstructure. Since substructure, sidewalks, barrier, and utility installation are similar for each structure type, only the deviations will be noted.

The complex construction sequence of the Reno Railroad Corridor Project currently allows a short period of time for the construction of each overhead. A time period of only 3 months has been allotted for some of the simple structures. Crossings that are wider or experience more traffic control are to be completed in 5 months or less. Since the construction time for the substructures of the alternate structure types are comparable and the substructures are partly constructed concurrently with the trench wall system, this report will only examine the construction time for the superstructure of each of the overhead types. The primary reason for a short timetable for the construction is to allow current levels of traffic on the structure as soon as possible. Since the sidewalks and railing can be added while the overhead is in use by vehicular traffic, provided that temporary barriers are installed, the time required to complete the sidewalks, barriers, and railings is not addressed in this report.

Time considerations involved in relocating the rail and other infrastructure items are not covered in this report.

The first step in the construction process of each structure is to begin trench excavation. The trench should be excavated sufficiently to allow for construction of forms and falsework or for the placement of pre-manufactured elements. In the case of cast-in-place alternate structure types, working surface preparation is included in the estimated initial excavation time required. The required time estimated for initial excavation and working surface preparation is 1-2 weeks. Working surface preparation includes the procedures required to create a working surface to support construction forms as needed.

Structure types requiring cast-in-place concrete will require time for curing. A full 28-day cure would be required to obtain sufficient strength, allowing traffic on the overhead. However, this time may be reduced through the use of concrete admixtures that produce high early-strength concrete. Depending on the conditions, these admixtures could reduce the curing time by up to 75%.

2.1.2 Construction Costs

Providing accurate cost data during preliminary engineering is challenging given the complexity of the project. The large number of overheads (11) along with the complications involved in scheduling the many different tasks involved in constructing the trench, shoofly, and overheads add to the difficulties in providing cost data for the project. However, by utilizing historic cost data, collaboration with contractors, materials fabricators, and professional judgement, we have estimated the cost per square foot of the overhead area (measured in plan). When considering the total cost of each structure type, it is important to make note of the plan area of each structure type as well as the cost per square foot. Some structure types, namely box beams and through girders, may require a larger plan area in order to obtain the same number of traffic lanes as discussed in the detailed portions of this report.

The costs calculated incorporate superstructure steel and concrete, abutment steel and concrete, concrete barriers, railings, excavation, and backfill. The abutment steel and concrete is based on using a 3-foot thick slurry wall as proposed in the Analysis of Wall and Invert System Report. The excavation quantities include the cost to excavate for the abutments, but does not include the initial excavation for the overhead cost, which is assumed to be included in the trench construction costs.

Pay Item	**Items Included**
Bar Reinforcing Steel	Superstructure reinforcement bars Substructure reinforcement bars
Structural Concrete, Bridge (Superstructure)	Concrete in the superstructure (f'c=4,000 psi)
Structural Concrete, Bridge (Substructure)	Concrete in substructure (f'c=3,500 psi)
Structure Excavation	Excavation for the abutments
Structure Backfill	Backfill around abutments
Miscellaneous Metal	Railings
Structural Steel	

Table 2 Payment Items

2.1.3 Utility Considerations

When comparing the feasibility of each overhead type, it is important to consider the location of utilities on the overhead. Some structure types require placement of the utilities while the overhead is being constructed, which will lengthen the construction time.

In some instances, the location of the utilities can create clearance conflicts. If large utilities must be hung below the superstructure, the required vertical clearance must be accounted for.

All of the wet utilities (gas, sewer, storm drain, water) that are not enclosed within the superstructure of the overhead must be encased. Casings may not be required for closed cell structures, which would allow for larger utilities; however, prior approval of the utility companies is required. If the wet utilities are enclosed within the superstructure but not encased then access holes and drains must be provided.

Utility requirements vary by structure location, creating their complex selection criteria. Based on location and required utilities, some structure types were eliminated from contention. Table 3 presents the utilities that will be carried by each overhead. The exact locations and loads of the power and cable television utilities are unknown at the time of this report. For the purposes of preliminary design, both were assumed to cross at each structure.

Location	Power*	Cable TV	Telephone Utility Weights	Utility pipes	Casing sizes
Keystone Ave.	E	E	158 plf	NP	NP
Vine St.	E	E	NP	12” water pipe 8” gas pipe	16” casing 12” casing
Washington St.	E	E	NP	24” water pipe 8” gas pipe	28” casing 12” casing
Ralston St.	E	E	135 plf	10” water pipe	14” casing
Arlington Ave.	E	NP	NP	NP	NP
West St.	E	E	NP	NP	NP
N. Sierra St.	E	NP	310 plf	NP	NP
N. Virginia St.	E	NP	114 plf	NP	NP
N. Center St.	NP	NP	NP	NP	NP
Lake St.	E	NP	315 plf	24” S.S. force main	28” casing
Evans Ave.	NP	NP	NP	NP	NP

Table 3 Utilities to be Carried by Overheads

E = Existing utility at intersection. It is anticipated that the utility will be carried by the overhead.
NP = None Predicted to be carried by the overhead
* = The weight is expected to be a maximum of 70 plf (Sierra Pacific Power Co.)

2.1.4 Overall Construction Impacts/Bridge Width

Effects to the remainder of the project are 1) Construction noise levels, 2) Traffic control and pedestrian impacts, and 3) Trench excavation. Using the Preferred Alternative (Alt. 5) to be depicted in the *Final Environmental Impact Statement*, overheads will be constructed at each railroad crossing from Keystone Avenue to Evans Avenue.

Although noise from construction vehicles will have an effect on the neighboring community, the difference in noise levels between the structure types is insignificant and was ignored for the purpose of this report. The noise from the superstructure construction is insignificant when compared with the concurrent trench construction.

The construction of any structure type will effect the vehicular and pedestrian traffic in the surrounding area. The placement of required cranes, the large numbers of construction vehicles requiring access to the structure daily, and the nearby area required for staging are examples of some of the items that may effect vehicular and pedestrian traffic in the vicinity of the construction. Structure types that reduced or had limited impacts to the surrounding area were favored.

In addition, the time between the beginning of construction and when vehicular and pedestrian traffic is allowed on the overhead was considered. Construction of the overheads may impact trench excavation. If the construction time required for each structure is too long then the excavation of the trench may be impacted.

Structure types that did not delay the excavation of the trench were given highest consideration.

The required structure width of each superstructure type is considered. Any problems relating to the width are discussed. The superstructure width will effect any adjacent structures such as the Fitzgerald's parking garage and the National Bowling Center structure. In addition, the number of traffic lanes and the size of the sidewalks may be restricted by the geometry of the structure.

2.1.5 Superstructure Depth

A minimum clearance of 23-feet is required between the top of rail and the bottom of the superstructure for the entire width of the trench. Each structure should fit within a prescribed envelope of 4-feet, at all locations except Keystone Avenue. The 4-foot envelope includes the superstructure depth plus consideration of a 2% cross slope on the local streets. Some of the structure types offer a much smaller structure depth than others, allowing the rail profile grade to be raised later in final design if desired. Raising the rail profile may result in decreased construction costs to the trench and wall systems.

2.1.6 Application

A discussion of where the structure type is applicable is provided in the detailed sections of this report. Any special circumstances in which the structure type might be used are discussed.

2.1.7 Conceptual Calculations

Assessing the feasibility of each structure type concrete strength and loads were considered. For simplicity, a single structure (North Central Street) was used to develop these assessable parameters.

The typical design strength for concrete ranges from 3,500- to 5,000-pounds-per-square-inch (psi) for cast-in-place and precast construction, respectively. Strengths above these typical values are attainable at additional costs associated to materials and quality control. Specifically, 6,000- to 7,000-psi strength would cost about 10-20% more than 4,000-psi concrete for cast-in-place methods.

Proper analysis of any structure type requires examination of the proposed structure's capacity to support the intended loads. Since self-weight varies, based on the structure type, only added dead load and live load are summarized in Table 5.

Live Load:

Each structure type was examined for HS20-44, Permit (P-13), and alternative military vehicles, as specified in AASHTO section 3.

In addition, added dead load must be considered. The added dead load is composed of future asphalt concrete overlay and utility weights as shown in the following table.

Added Dead Load:

Location	AC Overlay*	Sidewalk Barrier Railing*	Dry Utilities	Wet Utilities**	Total
Keystone Ave.	2.80 klf	3.30 klf	158 plf	0	6.26 klf
Vine St.	1.54 klf	3.30 klf	0	240 plf	5.08 klf
Washington St.	1.12 klf	3.30 klf	0	477 plf	4.90 klf
Ralston St.	1.12 klf	3.30 klf	135 plf	124 plf	4.68 klf
Arlington Ave.	1.96 klf	3.30 klf	0	0	5.26 klf
West St.	1.54 klf	3.30 klf	0	0	4.84 klf
N. Sierra St.	1.54 klf	3.30 klf	310 plf	0	5.15 klf
N. Virginia St.	1.96 klf	3.30 klf	114 plf	0	5.37 klf
N. Center St.	1.54 klf	3.30 klf	0	0	4.84 klf

* These weights are estimates. Actual weights will vary depending on the structure type selected.
** The wet utility loads include the weight of encasement. For structure types not requiring encasement these values may be reduced.

Table 4 Added Dead Loads

Helping optimize the structural sections, the total added dead load of the barriers and sidewalk could be reduced by up to 20% through the use of lightweight concrete.

Proper examination of each structure type must include preliminary seismic evaluation. Based on the seismic data provided and with experience in structural design, the indicated values will not eliminate any proposed structure type.

Seismic Criteria (NDOT as adopted from AASHTO):

Depth to bedrock:..> 150 ft

Acceleration:...0.42g (May be reduced through the use of site specific seismic criteria)

Other Loads:

In addition to the loads defined above, the final structure design will need to address wind loading.

The wind loading applied to a clear span of 54-feet is based on a wind velocity of 100 mile per hour (AASHTO, SSHB 3.15).

Overhead Properties:

For the basis of design, the following overhead parameters are consistent throughout the structure types examined.

Overhead length:.. 59’± (54’ clear span)

Superstructure f’c:.......................................4000 psi

Reinforcement Steel f_y: ....60000 psi

2.1.8 Precast vs. Cast-In-Place

When examining the different structure types, some consideration should be given to the differences between precast and cast-in-place concrete construction practices.

Precast concrete is typically more expensive than cast in place concrete due to stringent quality control requirements and shipping costs. The large number of precast units proposed for a project of this size makes the precast option more affordable.

Precast options will require the use of a crane in order to place the members. The crane, approximately 25’ x 34’ measured in plan, should fit within the trench and should have minimal impact to the traffic in the surrounding area.

The major advantage of precast concrete is the resulting shorter construction time, often times offsetting the additional cost. Use of the precast units can reduce traffic detours thus minimizing the impact to the surrounding businesses and residents.

2.1.9 Prestressed vs. Conventional Reinforcement

Prestressed concrete costs are slightly higher than conventionally reinforced concrete, but allows for the use of lighter/shallower sections. Prestressed concrete provides greater corrosion protection than conventional reinforcement. It provides for a better means of long-term deflection control[2].

3 Through Girder

3.1 Methodology

Although through girder sections are commonly used for railroad structure, they are uncommon for highway overheads. Exterior girders, located above and outside the roadway deck, distinguish this structure from the other structure types. Due to these girders, the overall structure width of a through girder overhead is wider than traditional highway structures carrying an equivalent number of traffic lanes. These exterior girders also present an obstruction to traffic at or near intersections, requiring additional detailing of crash cushions to address safety concerns. Furthermore, the soffit slab is relatively thick and oftentimes requires post-tensioning to span between girders. However, transverse post-tensioning is costly and would eliminate a through girder as a viable structure type. The minimal encroachment of the deck slab on the vertical clearance is the most prominent advantage of a through girder structure.

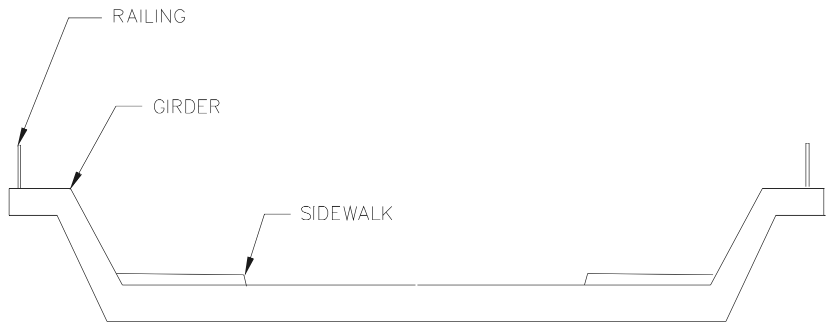


Figure 3 Through Girder Section

3.2 Conceptual Calculations

Based on the loading outlined in Section 2.1.7 of this document, a preliminary structural section was determined. The through girder typical section consists of a 1’-6” cast-in-place concrete deck with 4 girders that are approximately 5’-3” deep. Minimizing the requirements for post-tensioning, all crossings except Evans are anticipated to be configured as twin parallel through girders. The overhead at Evans will require one through girder section, but will require a thicker slab due to the required overhead width. However, at Keystone Avenue, where the crossing must be designed for 6 lanes, even with the use of twin through girders, the soffit slab thickness required would exceed practical structure limits necessitating transverse post-tensioning. The cost associated with transverse post-tensioning eliminates the through girder as a viable option at Keystone Avenue.

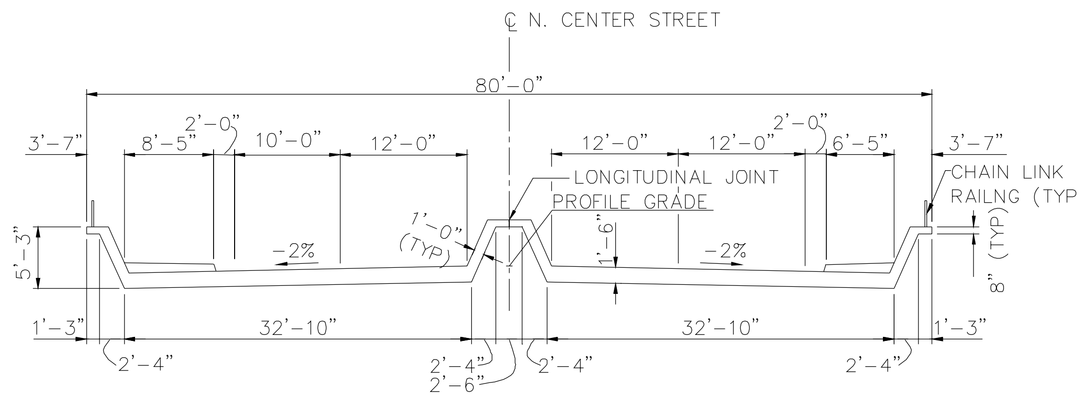


Figure 4 Through Girder Typical Section

The following is a summary of dimensions determined through completion of the conceptual calculations.

Overhead properties:

Overhead width:.. 80’-0”

Overhead depth:.. 5’-3” (without cross slope of deck)

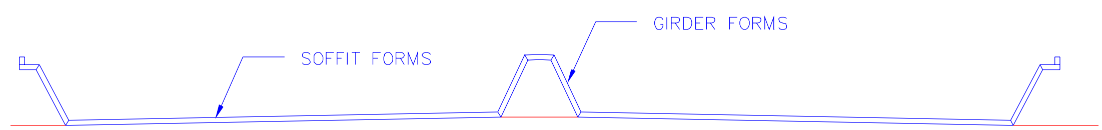
Depth of structure below profile grade: .... 1’-6” (without cross slope of deck)

3.3 Construction Duration/Sequence

The following section describes, in detail, the proposed construction sequence. This construction sequence is used to approximate the total construction duration. The details of Step 1 (preliminary excavation) have been described in Section 2.1.1.

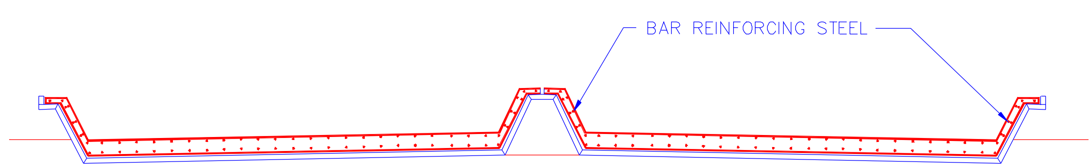
Step 2: Place forms for deck and girders

Exterior girder and deck forms are placed.



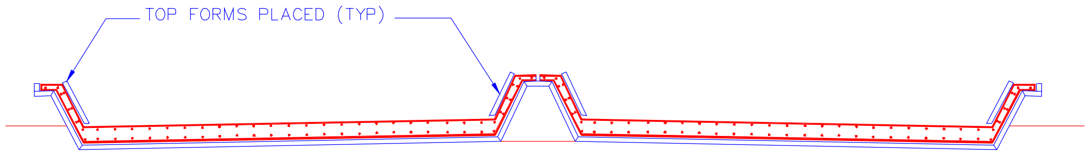
Step 3: Place bar reinforcing steel

Reinforcement for the entire superstructure is completed with this step.



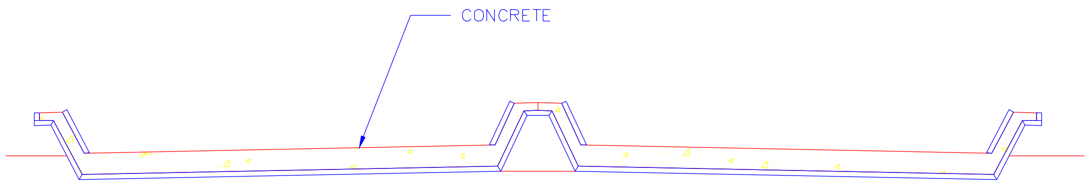
Step 4: Final detailing

The outside face girder forms are placed and the reinforcing steel is adjusted for proper spacing, alignment, and clearance.



Step 5: Place concrete

Concrete placement should be completed in a single pour.



Step 6: Concrete curing

The total construction duration for the through girder structure type, including the 3-4 weeks required for excavation and traffic control is 9-10 weeks.

3.4 Construction Cost

The probable construction cost for a through girder overhead is approximately $196 per square foot, based on a plan area of 4720 ft^2. The extra barriers and crash cushions required (discussed in the following sections) are not considered in the overall cost of the overhead. For a complete listing of the cost items considered see Table 2 in Section 2.1.2.

3.5 Utility Considerations

Utility pipes up to 2’-0” (24 inches) in diameter with a casing up to 2’-4” (28 inches) in diameter could be hung from the center girder without restricting the vertical clearance on the railway below. Additional utilities, limited by the same dimensions, could be hung from the exterior girders. However, placement of utilities adjacent to the exterior girders would negatively affect aesthetics.

Due to the location of the through girder, layout of the utilities at the abutments will be troublesome. On other structure types the utility would be sent straight through the backwall of the abutment. However, the girders on the through girder structure do not intersect a backwall. The utilities will either need to extend past the overhead and then dip down or dip down before reaching the abutment and go through the abutment stem. The former extends the obtrusive girder past the abutment. Once the crash cushion (Figure 6) is added to the end of the girder, the cushion will potentially obstruct the adjacent intersection. The latter will reduce the vertical clearance between the top of rail and bottom of soffit.

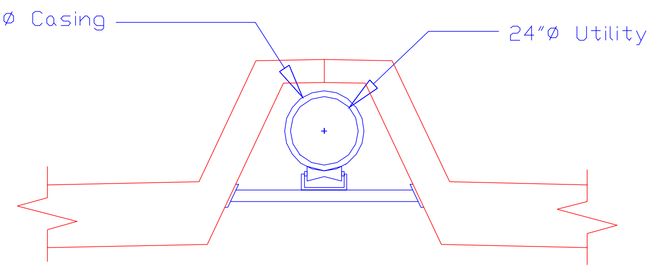


Figure 5 Typical Utility Connection Detail for Through Girder

3.6 Overall Construction Impacts/Bridge Width

If the structure is constructed with a cast-at-grade method, then a minimum of 2 weeks of curing is required before excavation beneath the structure can begin. However, if the structure is constructed after the installation of falsework, then the impact to the trench excavation is minimized.

The required crash cushion length requirement will not be acceptable at N. Arlington and West Street. At both locations the adjacent street, parallel to the rails, is too close to the trench.

The location of the girders above the roadway surface and between the traffic lanes presents a traffic hazard that requires the placement of crash cushions. Based on NDOT's Standard Plans, a crash cushion length of about 17-feet would be required.

The required bridge width for the through girder section is 80'at N. Center St. However, at locations such as Vine and Arlington the required width for the through girder section is larger than the right-of-way provided. Additional right-of-way must be purchased to use this structure at the three locations mentioned above. It should be noted that in order to obtain the 80-foot width at N. Center St. the sidewalk widths were reduced.

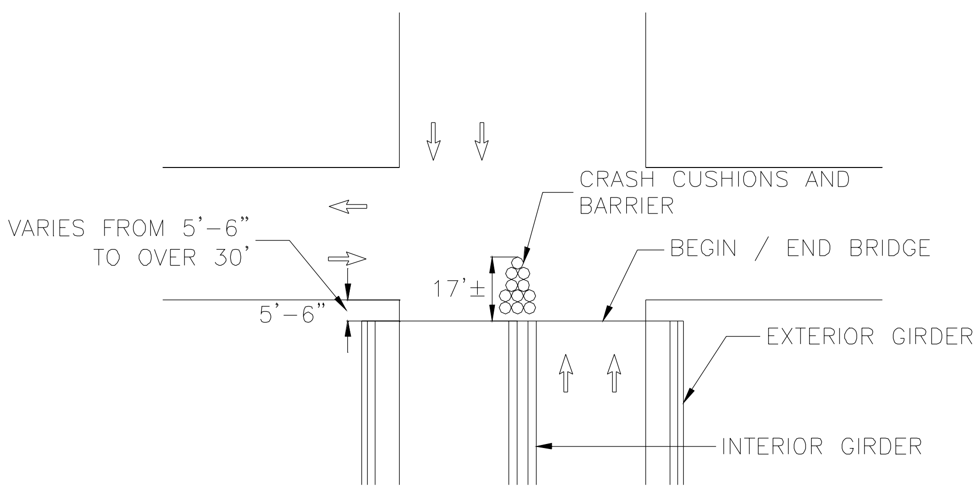


Figure 6 Crash Cushion at North Arlington Avenue

3.7 Superstructure Depth

The total structure depth, measured from profile grade to bottom of soffit, is 1’-6”. When a 2% cross slope is considered, the depth is between 2’-0” and 2’-6”. Therefore, this structure type fits within the established specifications, as described in Section 2.1.5, at all locations.

3.8 Advantages and Disadvantages of Through Girder:

The following is a brief list of advantages and disadvantages of the cast-in-place through girder structure type:

Advantages:

- Minimal structure depth below finish grade

Disadvantages:

- Obstructs vehicular sight distance
- Crash cushions required, possibly encroaching on adjacent intersections
- Longer construction time than overheads with precast elements
- Not typically used for highway structures
- Aesthetically obtrusive

3.9 Application

This structure type requires a larger width, at most locations, than the other structure types to obtain the same number of traffic lanes. The larger width exceeds the right-of-way width provided at Vine and Arlington. Without acquiring a larger right-of-way at these locations the through girder should be eliminated as an option at Vine and Arlington.

Furthermore, the through girder section is not applicable at Keystone Avenue due the added costs associated with the required transverse posttensioning.

In addition, this structure type would not be advised for overheads carrying a large number of utilities, such as Vine, Washington, Ralston, or Lake Streets. There is limited room within the girders to carry utilities, and carrying utilities beneath the soffit has the potential of interfering with the clearance envelope.

3.10 Conclusion

Although this structure type presents no conflicts with utilities nor with superstructure width requirements and could be used at North Sierra, North Virginia, North Center and Evans, it is not recommended for any of the Overheads due to the higher cost. Other structure types present a more economical solution, shorter construction time, and fewer utility conflicts.

4 Precast I-Girders With a Cast-In-Place Deck

4.1 Methodology

A precast I-girder structure is constructed of premanufactured beams resting on bearing pads at the abutments subsequently supporting an integrated reinforced concrete deck. Precast/prestressed I-girder overheads are commonly utilized for medium span solutions. The deck integration employs a positive connection between cast-in-place decks and the top flange of the beams through steel reinforcement. Using this technique, the deck can be shaped to specification. Adding flexibility to the design, precast deck forms may be used in lieu of removable deck forms where accessibility is poor.

Precast I girders are typically applicable to spans up to about 90 feet where erection of conventional falsework is not feasible or desirable. Such beams are particularly economical if conditions are favorable to mass fabrication or subject to time constraints.

The Federal Highway Administration and state highway departments have developed standard designs for precast/prestressed girder structures.

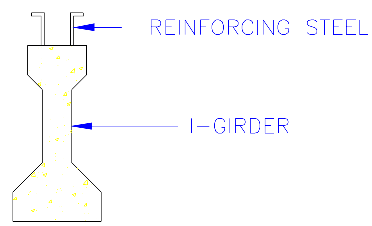


Figure 7 Standard I-Girder

4.2 Conceptual Calculations

Using the standardized tables and the loading criteria defined Section 2.1.7, a preliminary structural section was determined. This typical section consists of 13 precast/prestressed concrete I girders (AASHTO-PCI Type I) spaced at 6-feet 5-inches on center. These beams measure 16 inches in width (measured at the bottom flange), 28 inches in depth, and have a web thickness of 6 inches.

Based on the member sizes determined above, a sketch of the proposed section is provided in Figure 8 .

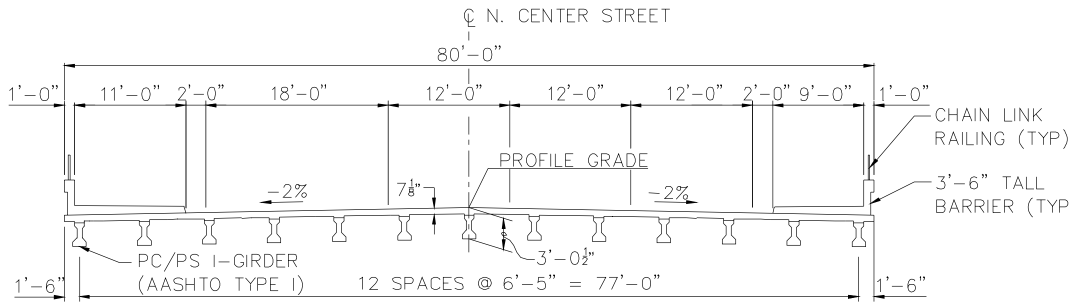


Figure 8 Precast/Prestressed I-girder Typical Section

In summary, the overhead section is as follows:

Overhead properties:

Overhead width:.. 80'-0"

Overhead depth:.. 3'-1" (without cross slope of deck)

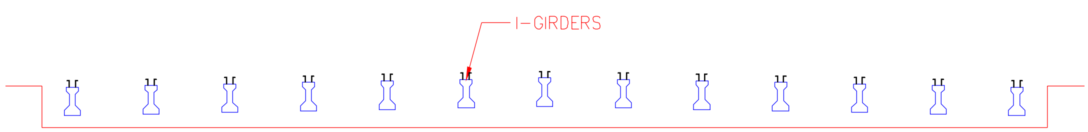
Depth of structure below profile grade: .... 3'-1" (without cross slope of deck)

4.3 Construction Duration/Sequence

The following section describes the proposed construction sequence used to determine total construction duration. The details of Step 1 (preliminary excavation) have been described in Section 2.1.1.

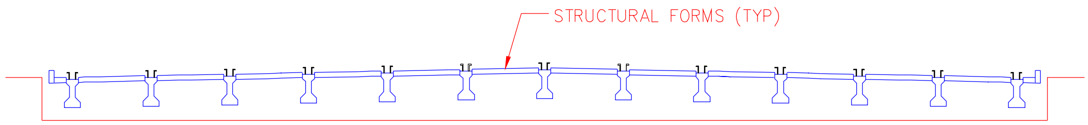
Step 2: Place I-girders (crane required)

After the precast girders are delivered to the job site, a crane is required for placement.



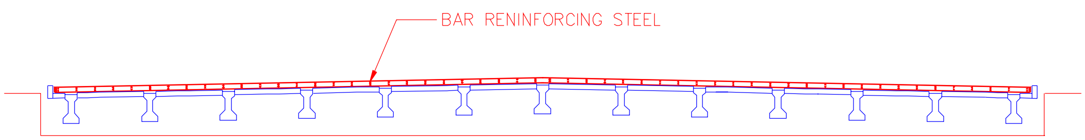
Step 3: Place forms for deck

The deck forms may be supported on the soil underneath the structure or be mounted on the sides of the girders. Precast panels may also be used as concrete deck forms.



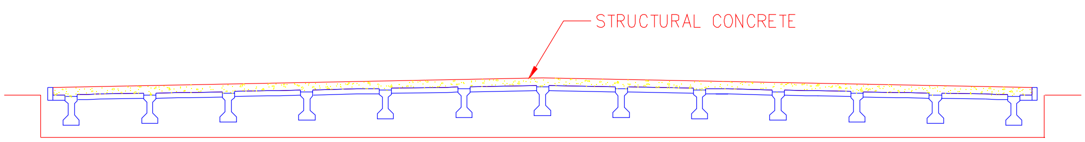
Step 4: Place Deck Steel

After the deck forms are placed, the deck reinforcing steel is placed.



Step 5: Pour concrete for deck

Concrete placement should be completed in a single pour.



Step 6: Concrete curing (28 days)

The forms can be removed once the concrete has obtained strength sufficient to support the self-weight of the deck. However, a full 28-day cure period is required before the barriers are placed and traffic is allowed on the overhead.

The total time required for construction, including 3-4 weeks for excavation and traffic control is 8-9 weeks. The longest portion of the construction will be the curing of the concrete deck.

4.4 Construction Cost

The 13 I beam units (AASHTO-PCI Type I), each 59' long, cost approximately \$5,000 per beam (delivered and installed). Based on a plan area of 4,720 ft^2, the unit cost for this structure type is \$188 / ft^2, the least expensive structure type.

4.5 Utility Considerations

Utilities can be hung below the deck between the I-girders. Being exposed to the environment these utilities will require more maintenance than enclosed in the superstructure of the box girder or the box beam. Although there are added maintenance concerns, the open superstructure allows for easy access to the utilities for replacement or repair. With the I-girder section the largest proposed utility pipe of 24-inch diameter with a 28-inch diameter casing can be hung beneath the concrete deck.

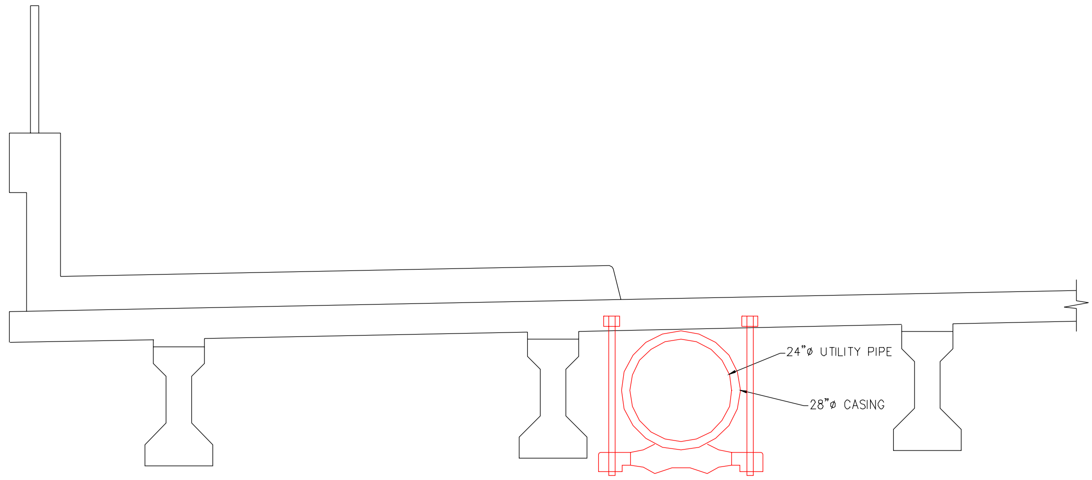


Figure 9 Typical Utility Connection for PC/PS I-Girder

4.6 Overall Construction Impacts/Bridge Width

A crane is required for pre-cast girder placement. This crane may interfere with the nearby traffic and will likely be in use for one to two days per structure. Throughout the construction process it will be necessary to reroute traffic to adjacent local streets.

In addition, storage of the precast girders will require a larger staging area than other cast-in-place structure types. However, the available storage areas inside the construction right-of-way are more than adequate for this temporary need. Overall, the impacts to the project area are minimal.

The structure type fits within the right of way at all location. No additional right of way is required.

4.7 Superstructure Depth

Using the standard section (AASHTO-PCI Type I), the total structure depth, measured from profile grade to bottom of soffit is 3’-1”. When a 2% cross slope is considered, the depth is between 3’-6” and 4’-0”, which fits within the 4-foot envelope described in Section 2.1.5, at all locations.

4.8 Advantages and Disadvantages of Precast/Prestressed I-Girders

Advantages

- Inexpensive, \$188 / ft^2 (deck width of 80-feet)
- Shorter construction time than cast-in-place structures
- Standard construction in Nevada

- Precast girders are manufactured within economic haul distance (Petaluma, CA approximately 200 miles)
- Utility access

Disadvantages

- Crane required in construction right-of-way

4.9 Application

Based on structural performance, utility flexibility and construction duration, this structure type applies to any structure throughout the Reno Railroad Corridor.

4.10 Conclusion

Precast/prestressed concrete I-girder structures are constructible, economically feasible and limit construction duration. Precast/prestressed concrete I-girders are recommended as the leading structure type for overhead structure construction in the Reno Railroad Corridor.

5 Cast-In-Place Reinforced Box Girder

5.1 Methodology

A box girder structure consists of open cells bounded by girders (exterior and interior), a deck (above), and a soffit (below). Extending beyond the open cells, the deck surface creates overhangs. Box girder structures are substituted for steel structures frequently when steel prices relative to reinforced concrete are high and because maintenance of concrete structures is significantly lower than steel structures. In addition, the geometric properties of box girder structures resist larger torsional forces. Traditionally reinforced, concrete box girder superstructures are typically used for span lengths of 50- to 120-feet. Preliminary determination of the total structural depth is accomplished with a depth-to-span ratio. In the case of box girder structures for highway loading, the commonly accepted design ratio yields a structure depth that is approximately 6% of the span length.

Adding to the benefits of torsional resistance and lower construction costs, box girders are considered to be one of the most aesthetic overhead types available due to their smooth lines and closed structure. Furthermore, the lifecycle costs of box girder structures are among the lowest of any overhead type.

Concrete box girder structures are constructed in phases. These phases include two concrete placement procedures, namely stem/soffit and deck pours. These independent pours, coupled with the intricate reinforcement detailing, lengthen the construction time required for completion of these structures.

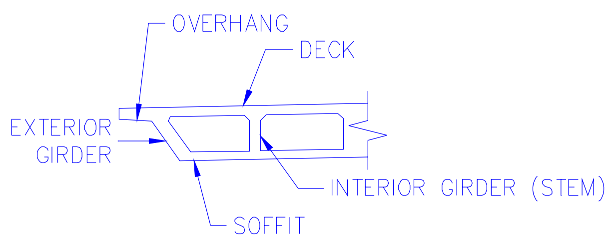


Figure 10 Box Girder

5.2 Conceptual Calculations

Based on a commonly accepted design span-to-depth ratio of 0.06, the superstructure depth should be about 3'-5". The box girder section allows for two 11-foot wide sidewalks while maintaining an eighty-foot superstructure width. The box girder typical section is comprised of a seven-inch thick deck, six-inch thick soffit, and fourteen girders (8-inches thick).

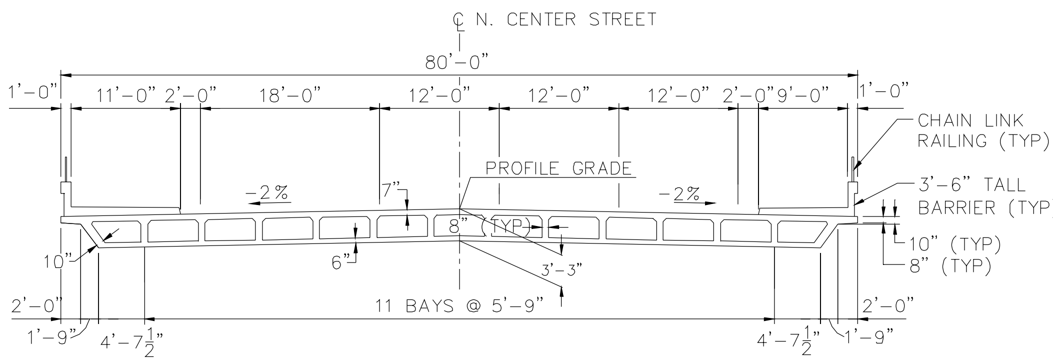


Figure 11 Box Girder Typical Section

In summary, the following describes the salient features of the typical section.

Overhead properties:

Overhead width:..80'-0"

Overhead depth:..3'-3" (without cross slope of deck)

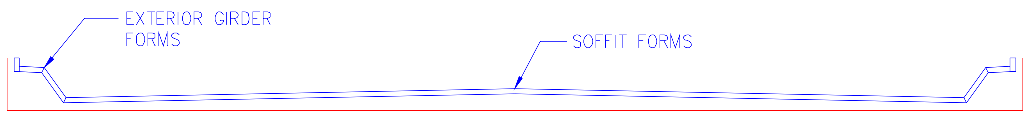
Depth of structure below profile grade: ....3'-3" (without cross slope of deck)

5.3 Construction Duration/Sequence

The following section describes, in detail, the proposed construction sequence used to determine total construction duration. The details of Step 1 (preliminary excavation) have been described in Section 2.1.1.

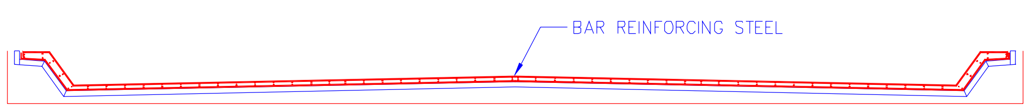
Step 2: Place forms

The forms for the soffit and exterior girders are placed.

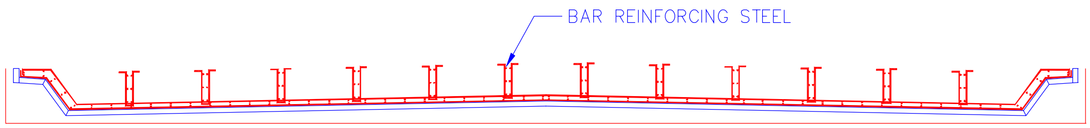


Step 3: Place Soffit Steel

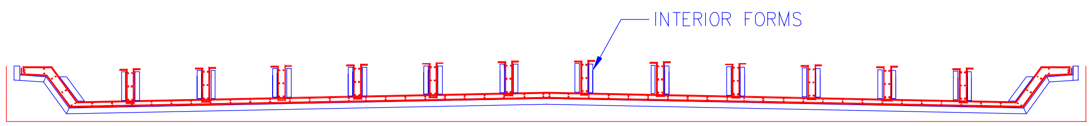
The steel for the soffit and the exterior girders are placed.



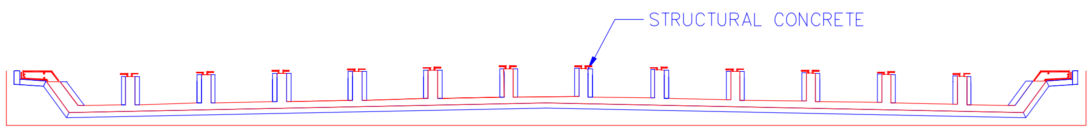
Step 5: Place Stem Steel



Step 6: Place Stem Forms

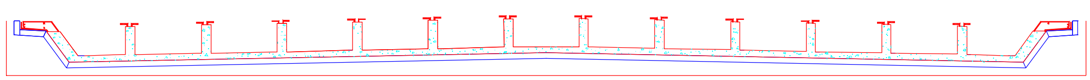


Step 7: Pour concrete for soffit and stems



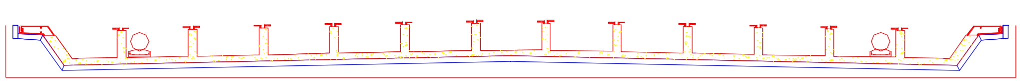
Step 8: Strip Forms and Cure (for utilities)

The backwall forms must be stripped for utility installation. The concrete must be cured adequately to support the utilities and the installation procedures and equipment prior to removal of the forms.

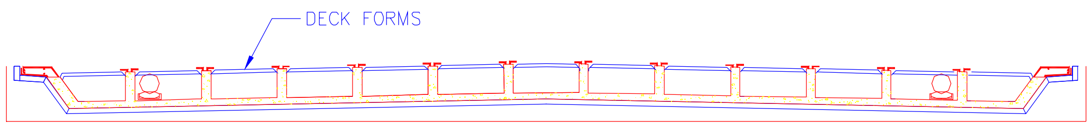


Step 9: Utility Install

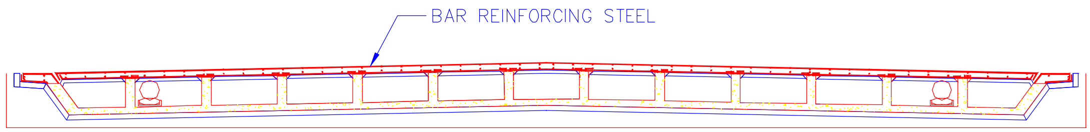
The utilities should be installed before the deck is placed. Placing utilities after the deck is poured is considerably more difficult. Placement of the utilities should take an average of about 1 week, with some overheads such as Washington and Vine taking up to 2-3 weeks.



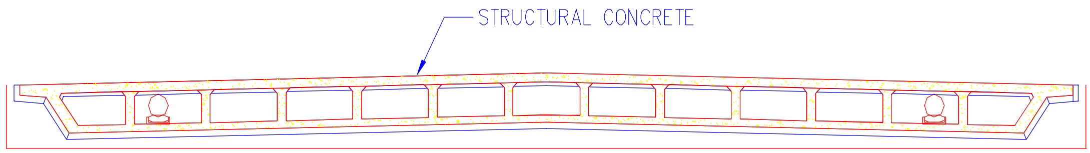
Step 10: Place forms for deck



Step 11: Place steel for deck



Step 12: Pour concrete for deck



Step 13: Concrete curing (28 days)

The total construction time for a box girder overhead, including 3-4 weeks for excavation, traffic control, and utility placement, is 11-12 weeks.

5.4 Construction Cost

The construction cost for a cast-in-place box girder is approximately $190 per square foot, based on a plan area of 4720 ft^2. This information was based on extensive cost data, through California. For a complete listing of the cost items considered see Table 2 in Section 2.1.2.

5.5 Utility Considerations

The box girder design allows the utilities to be enclosed within the superstructure, but limits the size of the utilities that can be installed. The largest utility that could be installed within the superstructure is 16 inches. However, utilities larger than this could be hung from the exterior girders. Utilities hung outside the structure would be clearly visible to traffic in the surrounding area and may negatively impact the aesthetics for this structure type as well as the clearance between the structure and the railway. From Table 3 in Section 2.1.3, the utilities at Washington and Lake will be too large to fit within the box girder and are too large to fit beneath the overhangs without exceeding the 4-foot depth restriction.

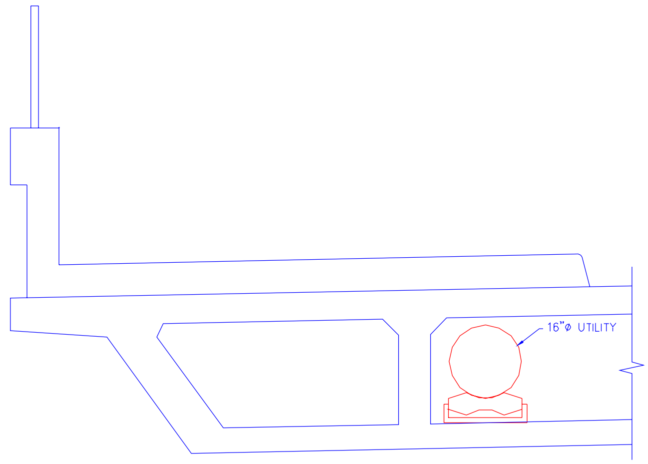


Figure 12 Typical Utility Connection for Box Girder

5.6 Overall Construction Impacts/Bridge Width

If the structure is constructed with a cast-at-grade method, then a minimum of 2 weeks of curing would be required before excavation beneath the structure could begin. However, if the structure is constructed after the installation of falsework, then the impact to the trench excavation is minimized.

The box girder fits within the right-of-way at all locations. No additional right-of-way purchases are required.

5.7 Superstructure Depth

The total structure depth, measured from profile grade to bottom of soffit is 3’-3”. When a 2% cross slope is considered, the depth is between 3’-8” and 4’-2”. This structure fits within the allowable depth, as described in Section 2.1.5, at all locations except Keystone Avenue (4’-2”).

5.8 Advantages and Disadvantages of Box Girders:

The following is a brief list of advantages and disadvantages of cast-in-place reinforced box girder:

Advantages:

- Economical, \$190 / ft^2 (deck width of 80-feet)
- Utility protection inside the cell
- Aesthetically pleasing
- Common construction details

Disadvantages:

- Construction time
- Requires access throughout construction (large trucks)
- Small cells restrict applicability to larger utilities

5.9 Application

Due to proposed utility sizes, this structure type is not applicable to the Washington Street and Lake Street overheads. In order to carry the proposed utilities at these locations, the superstructure must have a depth of 3'-11". When the 2% cross slope is considered, the depth would be 4'-4" to 4'-10" which violates the 4-foot envelope at all locations.

5.10 Conclusion

Although the box girder structure type is applicable for all of the overheads it is not the best structure type. The precast/prestressed I-girders are slightly more cost effective and result in a shorter construction time. For these reasons, the cast-in-place box girder is not recommended at any of the locations.

6 Steel I-girders With a Cast-In-Place Slab

6.1 Methodology

Steel I-Girder structures consist of rolled steel or built-up plate I-girders overlain with a cast-in-place concrete deck, all resting on bearing pads at the abutments. The deck slab is formed around shear studs welded to the flanges of the I-beams as seen in the Figure 13 below. Common span ranges for steel girder overheads are 60- to 300-feet. Steel girders are typically spaced at 7'-6" to 10'-6" apart and the recommended span to depth ratio, like reinforced concrete box girder overheads, provides a structure depth of approximately 6% of the span length.

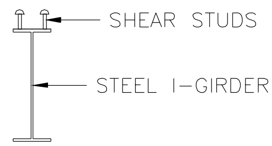


Figure 13 Steel I-Girder

6.2 Conceptual Calculations

Based on typical depth-to-span ratios, recommended girder spacing and preliminary analysis, this typical section is comprised of nine W30x191 steel beams with an 8¼" cast-in-place concrete deck. This section allows for two full-width sidewalks while maintaining a superstructure width of eighty-feet.

The spacing of the steel beams was chosen to satisfy the recommended girder spacing. Preliminary calculations were performed to determine the beam sizes required using standard A36 steel (ASTM steel classification).

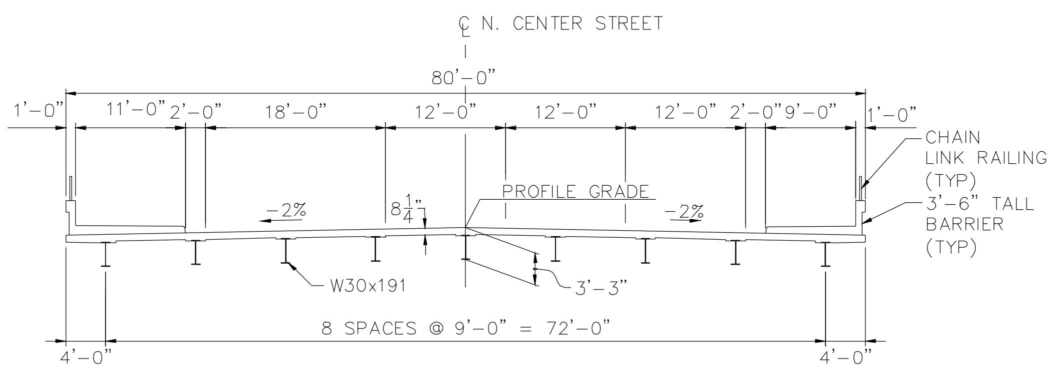


Figure 14 Steel I-Girder Typical Section

Summarizing the previous calculations, the following list of values was used for cost and application analysis.

Overhead properties:

Overhead width:.. 80'-0"

Overhead depth:.. 3'-3" (without cross slope of deck)

Structural Steel (f_y)......................................36 ksi

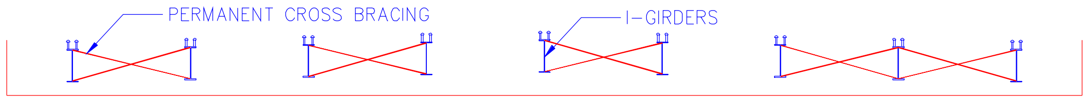
Depth of structure below profile grade: ....3'-3" (without cross slope of deck)

6.3 Construction Duration/Sequence

The following section describes, in detail, the proposed construction sequence used to determine total construction duration. The details of Step 1 (preliminary excavation) have been described in Section 2.1.1.

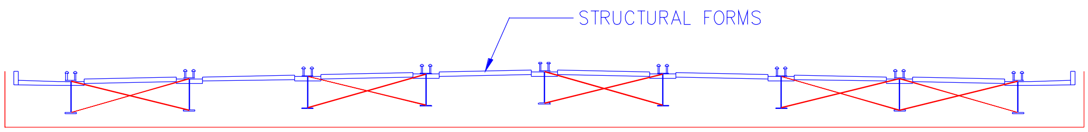
Step 2: Place steel I-girders (crane required)

A crane will be required to place the girders. The crane will likely be situated within the trench. Permanent cross bracing will be placed in alternating bays.

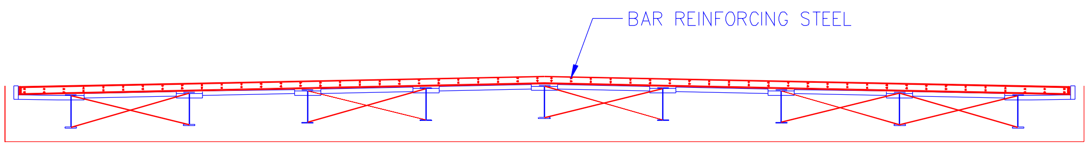


Step 3: Place forms for deck

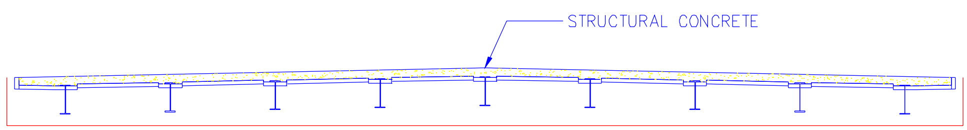
Once the girders are placed, the forms for the concrete deck can be placed.



Step 4: Place deck steel



Step 5: Pour concrete for deck



Step 6: Concrete curing and removal of forms

The construction, including 3-4 weeks for excavation and traffic control is expected to take 8-9 weeks with the majority of the construction time as a result of the curing period of the concrete deck.

6.4 Construction Cost

Nine W30x191 steel girders are required at a cost of $39,450/each, including materials and labor. In addition to the girders the concrete deck is expected to cost about $12.80 / ft^2.

The total construction cost of this structure type is about $267/ft^2. In addition to the higher construction costs of this structure type, a higher maintenance cost is expected. The steel girders will require continuous painting for corrosion prevention.

6.5 Utility Considerations

Utilities can be hung from the concrete deck between the steel girders. This structure type allows for a 24" diameter wet utility with a 28" diameter casing. The vertical clearance between the utility and the underlying tracks govern the maximum utility size that may be hung from the structure.

The open superstructure allows for easy access to the utilities for replacement or repair. The open superstructure will also require continued inspection and maintenance.

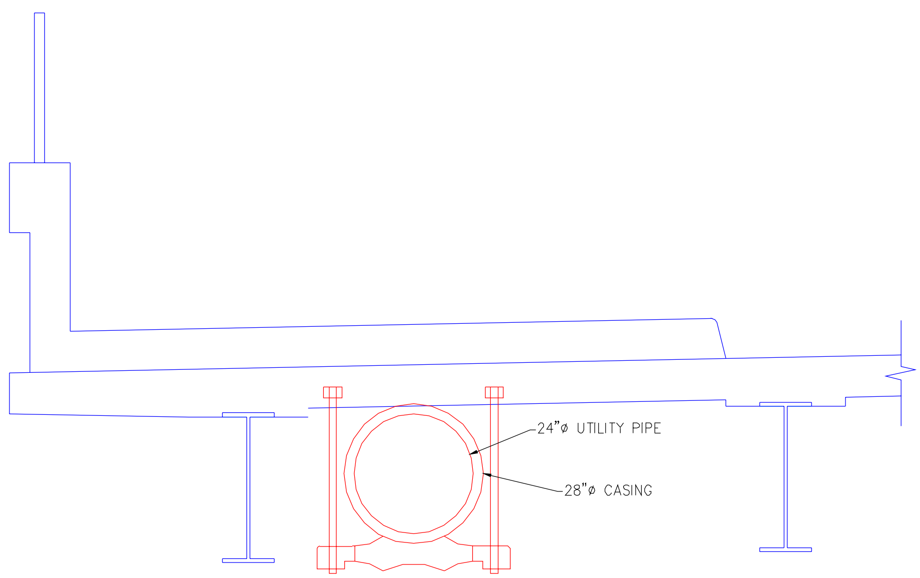


Figure 15 Typical Utility Connection for Steel I-Girder

6.6 Overall Construction Impacts/Bridge Width

A crane is required for pre-cast girder placement. This crane may interfere with the nearby traffic and will likely be in use for one to two days per structure. Throughout the construction process it will be necessary to reroute traffic to adjacent local streets.

In addition, storage of the precast girders will require a larger staging area than other cast-in-place structure types. However, the available storage areas inside the construction right-of-way are more than adequate for this temporary need. Overall, the impacts to the project area are minimal.

The required width of the steel I-girder section fits within the right-of-way provided. No additional right-of-way purchases are required.

6.7 Superstructure Depth

Using the standard section (W30x191), the total structure depth, measured from profile grade to bottom of girder is 3'-3". With consideration of the 2% cross slope, the depth is between 3'-8" and 4'-2", which falls within the 4-foot envelope, as discussed in Section 2.1.5, at all locations except Keystone Avenue (4'-2").

6.8 Advantages and Disadvantages of Steel I-Girders

The following is a brief list of advantages and disadvantages of steel I-girders:

Advantages:

- Construction time
- Standard construction in Nevada
- Materials within economic haul distance (possible fabricated and/or stored at Reno Iron Works)
- Utility access

Disadvantages:

- Costly, \$267 / ft^2 (deck width of 80-feet)
- Higher maintenance costs for coatings

6.9 Application

Based on the detailed analysis, the steel girder structure type is applicable to all locations. The structure width is within applicable limits for all of the streets. The structure type has the capacity to carry the utilities at each location.

6.10 Conclusion

Although the structure type is applicable to all of the overheads, it is not recommended for any of the overheads. The higher cost of construction and maintenance for this structure type prevents it from being a preferred option.

7 Post-Tensioned Reinforced Concrete Slab

7.1 Methodology

Slab structures are typically the most cost-effective structural solution for spans up to 40 feet. However, for longer spans, the economic benefits reduce dramatically. Use of slabs over 40 feet in length generally requires post-tensioning. Oftentimes, slabs are cast with voids running longitudinally, thereby reducing the self-weight of the structure. However, when voided slabs are employed, the structure depth must be increased to carry the same load. For larger spans, deeper sections using higher concrete strengths are expected. There is a delicate balance between performance and cost-effectiveness with voided slabs.

7.2 Conceptual Calculations

Post-tensioned concrete slabs are typically applicable to span lengths up to 65-feet. Using the industry standard depth to span ratio (0.030), preliminary calculations indicate the required structure depth to be approximately 1'-9". However, with the potentially large added dead loads within the Central Reno vicinity (Table 4, Section 2.1.7), concrete strengths in excess of 10,000 psi were required to maintain the standard depth-to-span ratio. To reduce the required concrete strength to acceptable limits (6,000 psi or less), the depth of the slab must be increased to approximately 2'-4". The difference in cost between a 2'-4" solid slab with posttensioning and a 3' deep box girder structure is considerable. Since the depth of 2'-4" and the required compressive strength of concrete are beyond practical and economic limits, the post-tensioned concrete slab was eliminated as a viable structure type.

8 Bulb Tee

8.1 Methodology

Precast/prestressed concrete bulb tee beams have been used successfully for highway structures since the 1970's. The bulb tee section is similar to an I-girder with thicker and wider flanges. The bulb tee is also related to the double tee section, which was initially considered. The double tee is typically used for spans from 30- to 60- feet. However, the large added dead loads preclude the applicability of the 54-foot clear span.

Oftentimes, use of bulb tees eliminates the need for a deck to be installed. Their use is typically required when cast-in-place structure types are infeasible or undesirable for medium length spans. Bulb tee beam sizes and details have been standardized by American Association of Highway and Transportation Officials (AASHTO) and Precast/Prestressed Concrete Institute (PCI).

A typical overhead section consists of a series of precast/prestressed bulb tee beams arranged parallel to one-another and placed contiguously. After placement, the adjacent beams are attached to one-another by grouting and/or welding methods. Precast bulb tee beams are readily available in 3 standard sizes that allow the structures to meet the clearance requirements of the Reno Railroad Corridor project. A combination of these standard beam sizes can be utilized to meet width requirements of various structures. When completed, these structures appear similar to facilities constructed of precast/prestressed I-girders. Below is a list of the standard sizes and maximum span lengths:

Designation	Width (ft)	Depth (in.)	"z" in.	Weight (lb/ft)	Area (in. ^{2})	I_X (in.^{4})	Y_b (in.)	*Maximum Span Lengths (ft)
A	4	34	0	627	602	88,310	20.38	97
B	5	29	1	708	680	64,110	18.48	67
C	5	34	0	690	662	95,180	21.39	80
D	5	41	1	771	740	157,840	26.18	100
E	6	29	1	771	740	67,790	19.13	62
F	6	34	0	752	722	100,600	22.25	74
G	6	41	1	833	800	166,.390	27.11	92
H	7	29	1	833	800	70,930	19.68	58
I	7	41	1	896	860	173,760	27.90	88

* These values are based on a standard HS-20 loading and may require adjustment when added dead load is considered.

Table 5 Bulb Tee Span Table

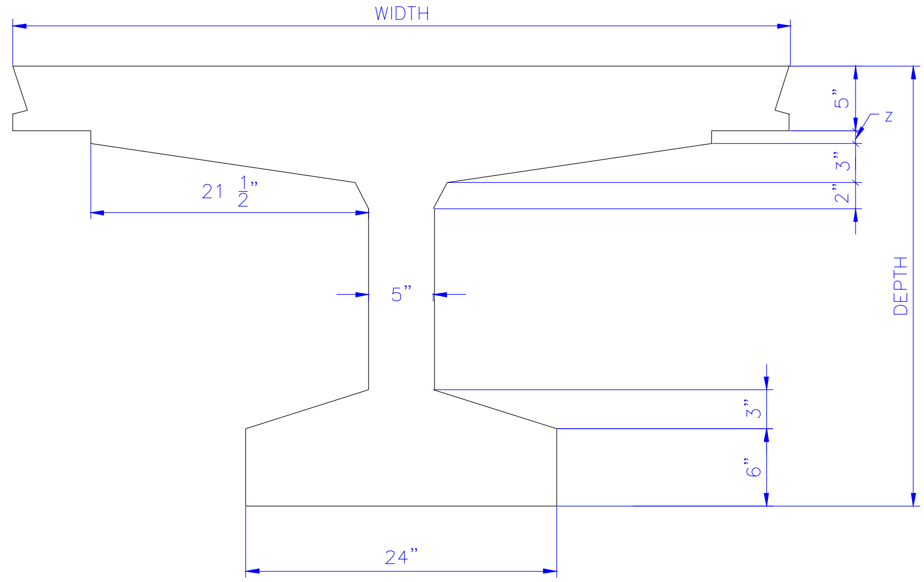


Figure 16 Bulb Tee

8.2 Conceptual Calculations

Using the standardized tables provided by AASHTO-PCI and the loading criteria defined in the introduction, the structural section was determined. This typical section consists of 14 precast/prestressed concrete bulb tee beams (2- Type "A" and 12-Type "F"). The top and bottom flanges of these beams measure 48- and 24-inches in width, respectively. Each beam is 34-inches in height, and has a web thickness of 5-inches.

Improving the serviceability of this structure type, an asphalt concrete overlay should be applied before opening the structure to traffic. Based on the member sizes determined above, a sketch of the proposed section is provided in Figure 17.

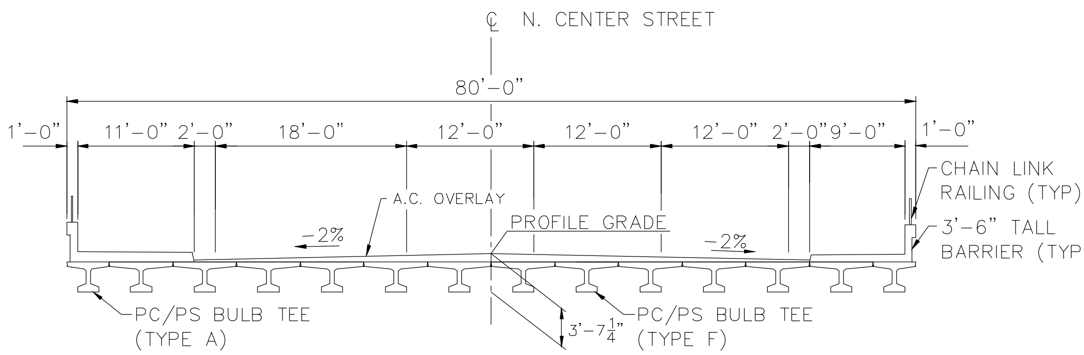


Figure 17 Bulb Tee Typical Section

In summary, the overhead section is as follows:

Overhead properties:

Overhead width:.. 80'-0"

Overhead depth:.. 2'-10" (without cross slope of deck)

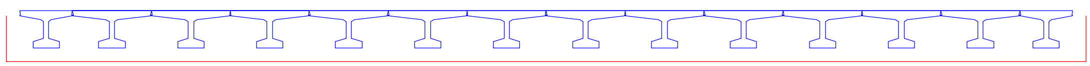
Depth of structure below profile grade: .... 2'-10" (without cross slope of deck)

8.3 Construction Duration/Sequence

The following section describes, in detail, the proposed construction sequence used to determine total construction duration. The details of Step 1 (preliminary excavation) have been described in Section 2.1.1.

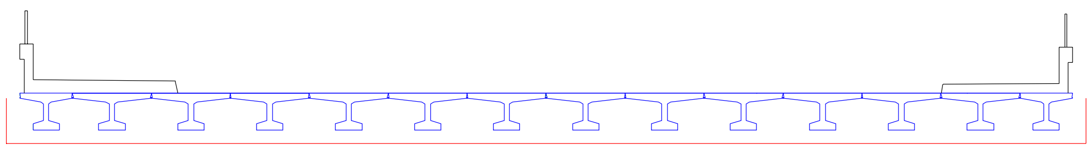
Step 2: Place beams

After delivery onto the job site, a crane must be used in order to place the precast concrete members.



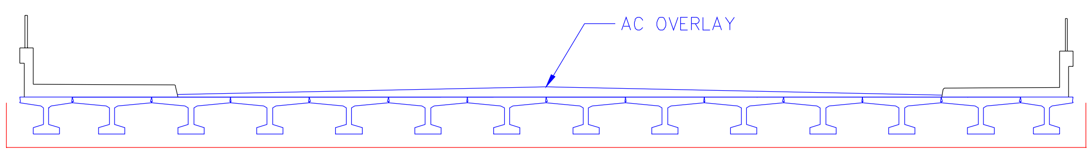
Step 3: Barrier Placement

Before AC overlay can be placed the sidewalks and barriers must be installed.



Step 4: Place AC overlay

The precast members are placed and connected (through welding and/or grouting methods). Then an asphalt concrete wearing surface is placed. The placement procedure for the wearing surface requires basic and readily available construction equipment.



The total time for construction, including 3-4 weeks for excavation and traffic control is expected to be 6-7 weeks. This construction time could be reduced if traffic is allowed on the structure without the AC overlay. The AC layer is used as a wear-and-tear surface to prevent the long-term degradation of the concrete beams.

8.4 Construction Cost

Based on 20 (Type "A" and Type "F") bulb tee units, each 59' long, the total price[1] delivered and installed is approximately $11,800 per beam. Based on a plan area of 4720 ft^2, the unit cost for this structure type is \$201/ft^2, a moderately expensive structure type in the Reno Railroad Corridor.

8.5 Utility Considerations

Based on clearance between the beams, a 24-inch diameter utility sleeved with a 28-inch diameter casing cannot be carried by the structure without having a portion of the utility hang below the bottom of the girders. This situation is undesirable. Therefore, the bulb tee should be eliminated at each crossing where 24" diameter utility pipes must be carried.

Open structures increase contact between the atmosphere and the utilities, thereby increasing maintenance costs. However, when maintenance is required, these open structures allow for easy access to the utilities.

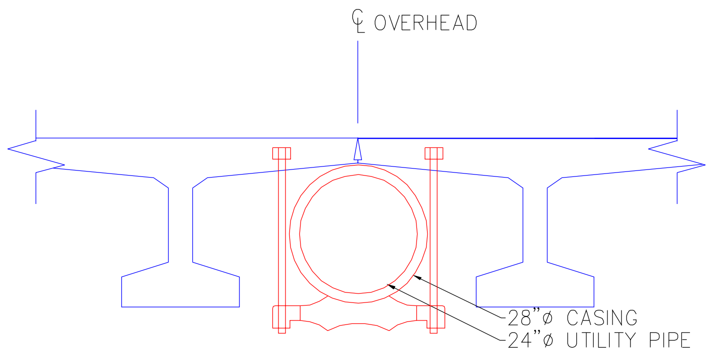


Figure 18 Typical Utility Connection for Bulb Tee

8.6 Overall Construction Impacts/Bridge Width

A crane is required for pre-cast girder placement. This crane may interfere with the nearby traffic and will likely be in use for one to two days per structure. Throughout the construction process it will be necessary to reroute traffic to adjacent local streets.

In addition, storage of the precast girders will require a larger staging area than other cast-in-place structure types. However, the available storage areas inside the construction right-of-way are more than adequate for this temporary need. Overall, the impacts to the project area are minimal.

The bulb tee section's required width fits within the right-of-way provided at all locations. No additional right-of-way purchases are required.

8.7 Superstructure Depth

Using the standard sections (Type "A" and Type "F") and considering the depth of AC required, the structure depth, measured from profile grade to bottom of girder, is between 3'-4" and 3'-10", which falls within the allowable clearance envelope of 4-feet, as described in Section 2.1.5, at all locations.

8.8 Advantages and Disadvantages of Bulb Tee Beams

Advantages

- Construction time
- Economic future widening of structure
- Materials within economic haul distance (Petaluma, CA)
- Utility access

Disadvantages

- Costly, \$201 / ft^2 (deck width of 80-feet)[1]

8.9 Application

The width of the superstructure required is appropriate for all of the crossings. The utilities that would be carried by the structure are within the capacity of the overhead and will not present a clearance problem.

8.10 Conclusion

Although this structure type is applicable to all of the locations, it is not the best structure type available. The cost of the bulb tee structure type (\$201 / SF) is higher than that of the precast I-girders. The advantages of a very short construction time do not make up for the higher costs (~\$85,000 for North Center Street).

9 Precast/Prestressed Concrete Box Beam

9.1 Methodology

Precast/prestressed concrete box beams have been used successfully since the mid-1950's. Their use is typically stipulated by the lack of feasibility for cast-in-place structure types that require higher torsional resistance and faster construction times than open girder options. Box beam sizes and details have been standardized by AASHTO-PCI.

A typical overhead section consists of a series of precast/prestressed box beams arranged parallel to one-another and placed contiguously. After placement, the adjacent beams are attached to one-another by grouting and/or welding methods. Precast box beams are readily available in 8 standard sizes. Below is a list of the standard sizes and appropriate span lengths:

Beam Type	Width "W" (in)	Height "H" (in)	Recommended Span Limit (ft)
BI-36	36	27	74
BI-48	48	27	73
BII-36	36	33	86
BII-48	48	33	86
BIII-36	36	39	97
BIII-48	48	39	96
BIV-36	36	42	103
BIV-48	48	42	103

Table 6 Box Beam Span Table

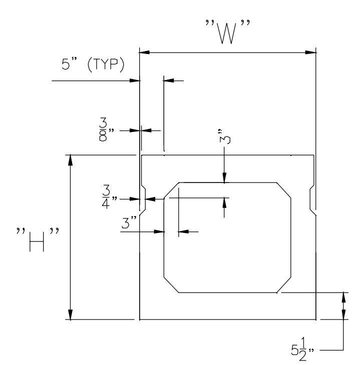


Figure 19 Box Beam

In addition, facilitating utility installation, the exterior beams may be one size larger than those used in the interior. By installing all beams with flush soffits, the concrete placed for the sidewalk will hide any visible difference in cell sizes. Using these larger beams increases the internal clearance provided allowing for larger pipes.

9.2 Conceptual Calculations

Using the standardized tables provided by AASHTO-PCI and the loading criteria defined in the introduction, the structural section was determined. This typical section consists of 27 precast/prestressed concrete box beams ([B I-36], [B II-36]). These beams measure 36 inches in width, 27 inches in height, and have wall thickness of 5 inches.

Improving the serviceability of this structure type, an asphalt concrete overlay should be applied before opening the structure to traffic. Based on the member sizes determined above, a sketch of the proposed section is provided in Figure 20.

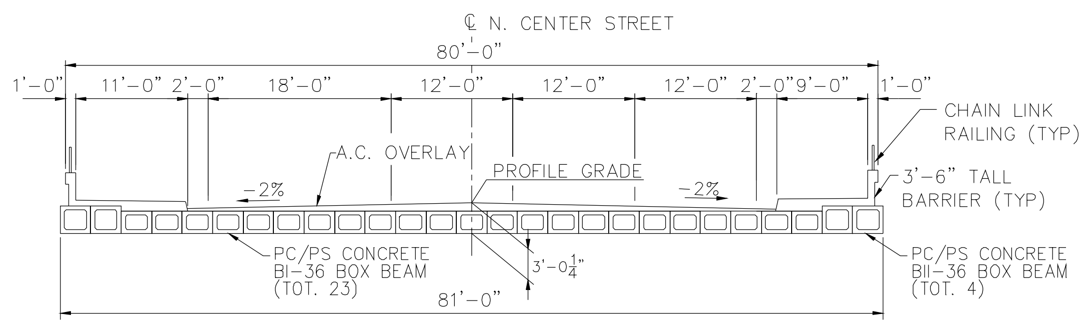


Figure 20 Precast Box Beam Typical Section

In summary, the overhead section is as follows:

Overhead properties:

Overhead width:.. 81'-0"

Overhead depth:.. 3'-0" (without cross slope of deck)

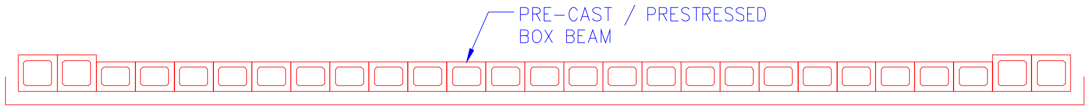
Depth of structure below profile grade: .... 3'-0" (without cross slope of deck)

9.3 Construction Duration/Sequence

The following section describes, in detail, the proposed construction sequence used to determine total construction duration. The details of Step 1 (preliminary excavation) have been described in Section 2.1.1.

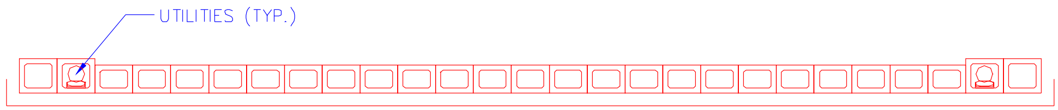
Step 2: Place box beams

Each box beam is lifted from delivery trucks by a crane, preferably operating within the trench right-of-way. Then, each beam is placed on bearing pads that have been installed on the abutment seats. After all beams are placed, the void spaces between adjacent beams are filled with grout.

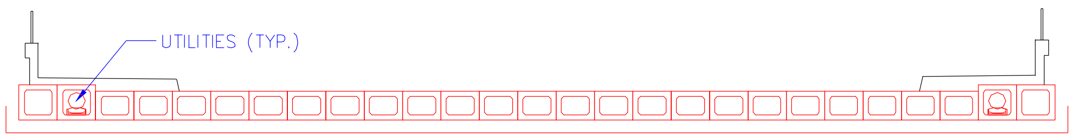


Step 3: Place utilities

The number of utilities being carried by the superstructure will effect the time required for placement.

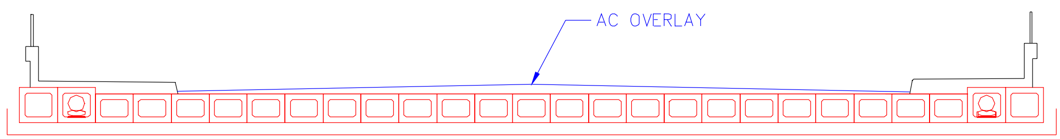


Step 4: Place sidewalks and barriers



Step 4: Place AC overlay

An AC overlay with a minimum thickness of two inches would be required on the structure before vehicles can be allowed on the overhead.



The total construction time, including 3-4 weeks for excavation, traffic control, and utility placement, is expected to be 6-7 weeks.

9.4 Construction Cost

Based on 27 ([B I-36], [B II-36]) box beam units, each 59' long, the total price[1] for each beam delivered and installed is $70/ft^2. Based on a plan area of 4779 ft^2, the unit cost for this structure type is $246/ft^2.

9.5 Utility Considerations

The depth of the structure does not allow utilities to be hung beneath the structure without impacting the 23-foot vertical clearance required between the bottom of the superstructure and the top of rail. Due to restricted clearance, the utilities carried on this structure type must fit within the box beams. Access to the utilities within the beams can not be provided so the wet utilities must be encased. A utility pipe with a diameter up to 12" can be carried in the beam (B II-36) without special end-diaphragm designs. This structure type is eliminated from consideration at Washington and Lake due to the utilities (Table 3) that must be carried by those overheads.

9.6 Overall Construction Impacts/Bridge Width

Closure of adjacent roads routinely occurs during overhead construction due to the requirements for staging areas and heavy equipment operations. However, with this precast structure type, impacts to local traffic will be less than casting-in-place methods. In addition, delivery trucks will only be needed for short periods; thereby forcing only temporary closures. Similar to other precast options, the impact to local traffic for box beam installation does not preclude it from being recommended.

The box beam section required superstructure width is 1-foot larger than the right-of-way provided at each location. Additional right-of-way purchases are required at each location.

9.7 Superstructure Depth

Using the standard sections ([B I-36], [B II-36]) and considering the AC layer with a 2% cross slope, the total superstructure depth is between 2'-7" and 3'-2", which fits within the allowable depth of 4-feet, as noted in Section 2.1.5, at all crossings.

9.8 Advantages and Disadvantages of Box Beams:

The following is a brief list of advantages and disadvantages of precast/prestressed concrete box beams:

Advantages:

- Construction time
- Future widening of structure is more economical
- Protected utilities
- Standard sections have been rated for highway loads (minimal design time)

Disadvantages:

- Costly, \$246 / ft^2 (deck width of 81-feet)[1]
- Small cells restrict applicability to larger utilities

9.9 Application

Structurally, precast/prestressed concrete box beams provide an adequate solution for short timeframe construction with limited construction right-of-way. These beams are especially attractive in situations that are more heavily leveraged for time due to liquidated damages or lost revenue. Since the proposed staging for Central Reno allows for local street closures for a period of 3 to 5 months, the added expense of this structure type is not justifiable. In addition, this structure type is not applicable at crossings that will carry wet utility pipes larger than 12-inches in diameter (Washington Street and Virginia Street).

Due to the standard box beam sizes, the width of the structure was required to be 81-feet, which exceeds the 80-foot right-of-way at several locations (Vine, Arlington, West, North Sierra, North Center and Lake). Additional right-of-way will need to be acquired or precast beams such as bulb tees can be used in place of the exterior box beams in order to obtain the required width.

9.10 Conclusion

Although this box beam provides an adequate structural solution to most of the overhead crossings in the Reno Railroad Corridor, it is not the leading structure type for any crossing. The high cost and utility restrictions offset the advantages of the accelerated construction schedule.

10 Results

Based on the research of each structure type, Table 7 has been developed to summarize our findings. In the table, each structure type is listed against the selection criteria and marked with a (•) for criteria that is satisfied at all locations and a (X) for criteria that are not satisfied at all locations. Any structure types with a (X) were eliminated as plausible structure types for the Reno Railroad Corridor project.

Location	Critical Screening Criteria			
	Construction Duration/Sequence	Construction Cost	Utility	Superstructure Depth
Through Girder	•	•	X	•
PC/PS I-Girder	•	•	•	•
CIP Box Girder	•	•	•	X
Steel I-Girder	•	X	•	X
PC/PS Bulb Tee	•	X	X	•
PC/PS Box Beam	•	X	X	•

Table 7 Screening Criteria

The above table uses screening criteria to eliminate structure types from consideration. The selection criteria included construction duration/sequence, construction costs, utility consideration, construction impacts/bridge width, and superstructure depth requirements:

Structures requiring more than 5 months to construct could impact the progress of the project. Therefore, any structure types requiring more than 5 months would have been eliminated from consideration. No structure type fell within this category.

The large number of overhead structures involved in the Reno Railroad Corridor project renders overhead construction costs as a major concern. The cost screening criteria was based on a selection of the three structure types with the lowest cost. The steel I-girder ($267/ft^2), PC/PS bulb tee ($201/ft^2) and the PC/PS box beam ($246/ft^2) were the three highest costing options and were eliminated from consideration.

Some structure types were eliminated based on the inability of the structure to carry the necessary utilities at a given location. The through girder, PC/PS bulb tee, and the PC/PS box beam structures that did not have sufficient room to carry the utilities, without impacting the vertical clearance between the structure and the rail, and were eliminated from consideration.

Structure types that did not fit within the allowable vertical depth window were eliminated from consideration. The steel I-girder and the CIP box girder were eliminated from consideration. Both structure types violated the 4'-0" window at Keystone Avenue.

11 Conclusions

The precast/prestressed I-girder section is applicable to all overcrossings, is the most economical, has a reasonable construction time, and has the capacity to carry the expected utilities. Therefore, the precast/prestressed I-girder is the preferred structure type for the Reno Railroad Corridor project. As an alternate structure type, for additional construction costs, the cast-in-place may be considered for all locations other than Keystone Avenue.

Appendix A

References:

1. Jon Grafton, Pomeroy Corporation, P.O. Box 2020, Perris, California, 92572, (909) 657-6093

2. Naaman, Antoine E., *Prestressed Concrete Analysis and Design Fundamentals*, McGraw-Hill, Inc., 1982.

Appendix B

Advanced Planning Study